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accelerated roadbuilding on the north umpqua

an economic analysis

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ABSTRACT

This study evaluates the economic desirability of accelerated roadbuilding for access to old-growth timber on a unit of the Umpqua National Forest in Oregon. As of 1966, four accelerated roadbuilding alternatives were found economically inferior to the then current rate of construction. Only in the case of substantial, continuing inflation were projected rates of return on investment for accelerated roadbuilding above 6 percent compound interest.

The inclusion of nontimber benefits and costs, changes in price and cost levels since 1966, and recent improvements in logging technology do not appear to alter this study's results appreciably.

Combined with the results of recent, published studies, the findings on the North Umpqua suggest that accelerated roadbuilding is not an attractive investment opportunity for National Forests in the Douglas-fir region.

Keywords: Forest roads, forestry economics, logging.

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SUMMARY

This study evaluates the economic desirability of accelerated roadbuilding on the North Umpqua unit of the Umpqua National Forest in southwestern Oregon.

Four alternatives, ranging from 1-1/3 to 6 times the current rate of roadbuilding in 1966, were evaluated by comparing their estimated additional benefits and costs. Additional benefits included timber volume from mortality salvage, prelogging, and thinning. Additional costs were interest charges and road maintenance from the time roads were completed under an accelerated program until they would have been completed at the 1966 rate.

When only benefits from timber harvesting were considered, no accelerated rate of roadbuilding was economically justified. The best alternative promised less than a 4-percent rate of return on investment. Reasonable changes in price and cost assumptions did not result in attractive rates of return for accelerated roadbuilding, with one exception: substantial, continuing inflation could raise rates of return to 7 percent or higher.

Inclusion of nontimber benefits and costs appears to further reduce the economic desirability of accelerated roadbuilding, primarily due to higher construction costs needed to limit damage to fisheries and water resources.

Improvements in logging technology and changes in price and cost levels since 1966 would not appreciably alter the results of this study.

Combined with the results of recent, published studies, the findings on the North Umpqua strongly suggest that accelerated roadbuilding is not an attractive investment opportunity for National Forests in the Douglas-fir region.

PURPOSE AND SCOPE OF STUDY

It has been suggested (Fedkiw 1961, Helburn 1947, McMahon 1961, Morse 1962, Public Land Law Review Commission 1970, Richen 1961, USDA Forest Service 1953)[1/] that public investment in an accelerated roadbuilding program on the National Forests would yield great benefits to the American economy. Allegedly, a faster rate of road construction would permit a higher annual cut of timber, increased utilization of non-timber resources, and improved protection and management of the National Forests. The value of these additional benefits is expected to exceed the additional expenditures necessary to attain them. For example, Fedkiw (1961) suggests the availability of an additional 1 to 2 billion board feet per year and rates of return on investment as high as 10 percent in the Pacific Northwest.

Despite these predictions of great economic benefits of accelerated roadbuilding, the economic analysis of road scheduling has been a neglected aspect of forest road planning. Road location and design have been subject to fairly sophisticated economic analyses (Matthews 1942, Silen 1955, Larsson 1959). Helburn (1947) argued for fast enough roadbuilding to harvest the allowable cut. Descriptive papers (Fedkiw 1961 and 1964, Richen 1961) have outlined the potential of faster roadbuilding. But until the "Douglas-fir Supply Study" (USDA Forest Service 1969) and the paper by Schallau (1970), there had been no published economic analyses of forest road scheduling.

Is accelerated roadbuilding on the National Forests economically justified? This study provides a method for answering this question and applies it to a sample National Forest unit, using data available as of 1966.

Roadbuilding an Important Investment

Road construction on the National Forests is a vital first step in forest management and protection. Roadbuilding is also the forest manager's most expensive single investment. In 1965, the planned road system on the National Forests was 513,503 miles, including existing roads (Ketcham 1965). Construction or reconstruction of 384,333 miles, mostly in the West, remained to complete the system. If these roads cost $25,000 per mile, an investment of $9.6 billion was needed.

Until the early 1950's, lack of access roads in the National Forests prevented harvest of the full annual allowable cut of timber[2/] (USDA Forest Service 1953). At the same time, demand for timber was strong, forcing stumpage prices up and creating strong pressures on the Forest Service to improve access and sell more timber (USDA Forest Service 1962). One result of this pressure was increased appropriations for Forest Service roads, which permitted attainment of the full allowable cut on most forests by the middle 1950's (Cliff 1956).

1/ *Names and dates in parentheses refer to Literature Cited, p. 18-20.*

2/ *The volume of timber that may be cut, under management, in a given year.*

The demand for timber has not slackened. For example, the average all-species stumpage price per thousand board feet (M bd. ft.) in western Oregon and Washington rose from $12.24 in 1950 to $37.05 in 1966, whereas total timber harvested increased only 13 percent during the same period (Hamilton 1970). Increased demand has produced continuing pressures on the Forest Service to sell more timber. These pressures now are directed at raising the allowable as well as the actual cut. One possibility of raising the cut is through accelerated roadbuilding.

Economically Sound Road Scheduling Decisions Needed

Road scheduling is the "when" of road construction as opposed to the "where" or the "what kind"; that is, it is concerned with the rate of roadbuilding rather than with road location or road design. The rate of roadbuilding can be expressed as the length of time to complete a given road network or, equivalently, the length of road completed in a given period of time. For example, if it takes 10 years to complete a road system of 1,000 miles, the rate of construction is either 1/100 year per mile or 100 miles per year.

If funds are available, the rate of roadbuilding is variable over a wide range, from no roadbuilding at all to a rate that would complete the system in only a year or two. Economic criteria can be used to determine an optimum rate of roadbuilding by comparison of the relative costs and benefits of alternatives throughout the range.

Building roads faster than needed for harvest of the annual allowable cut has been termed "advance roading" by Fedkiw (1961, 1964). Roads are built some time in advance of the final harvest cut for the primary purpose of removing volume not included in the calculated allowable cut. In 1966, this nonchargeable volume included mortality salvage, prelogging, and intermediate cuts to capture potential mortality.

Because timber access roads will eventually be constructed anyway, the only costs attributable to building them in advance are interest on construction costs until the time they would have been needed for final harvest cutting and their maintenance for the same period of time.

Available Budget Limits Roadbuilding Rate

Increasing the rate of roadbuilding on the National Forests would require greater spending until the road system was completed, even though total construction costs might be equal whether the system was built rapidly or slowly. But the amount appropriated for National Forest road construction is strictly limited during a given year, as is the allocation of these funds to individual National Forest units.

In practice, there is some flexibility in the road construction budget for an individual unit. To the extent that timber purchasers build roads as part of timber sale contracts, the road construction budget is increased. The amount of increase possible for a given sale can be calculated as $V(AP - MP)$, where V is the total timber volume, AP is the appraised price as if the roads were in place, and MP is the minimum price that the Forest Service will accept for its timber ($2 per M bd. ft. for Douglas-fir in

1966). Increasing the road allowance can lower the appraised price from a maximum of *AP* all the way to the minimum price. Thus, the Forest Service can manipulate sale size and location subject to appraised and minimum price constraints. Some advantage is taken of this opportunity by the staggered-setting method of timber harvesting practiced in the Douglas-fir region. But even if maximum advantage were taken of this opportunity, there is still a ceiling on the amount annually available for roadbuilding. This ceiling can be removed only by increased appropriations.

Case Study Approach Required

No single rate of road construction is optimum for every National Forest. Because conditions for road construction, timber management, and timber marketing are so variable from place to place, relatively small geographic units must be examined and the optimum rate of roadbuilding determined for each. For example, the results of a road scheduling study are expected to be quite different for young-growth versus old-growth forests, for areas of low versus high road construction costs, and for competitive versus noncompetitive timber market conditions. Thus, the optimum rate of road construction should not be calculated on a regionwide or nationwide basis but should be determined locally.

The North Umpqua unit of the Umpqua National Forest in southwestern Oregon was selected as the site of this study. The unit is typical of much National Forest land in the Douglas-fir region, containing predominantly overmature timber, much of it inaccessible.

The North Umpqua unit is composed of the Diamond Lake, Glide, and Steamboat Ranger Districts, all of which are drained by the North Umpqua River. No other National Forest land lies within the same basin. Thus, the unit boundaries coincide with the boundaries of a logical and complete road system.

The unit occupies about 575,000 acres, roughly 497,000 acres of which are classified as commercial forest land. This acreage supports 18 billion board feet of timber, about two-thirds of which is Douglas-fir. About 93 percent or nearly 17 billion board feet of the total volume is currently merchantable sawtimber 100 years of age or older, and about half of this 17 billion is at least 200 years old. Average site index is a medium-to-high site IV, fairly low compared with the region as a whole. Only about 30 percent of the planned road system was in place as of 1966. At the present rate of construction, 75 miles per year, completion of this road system will require 30 years.

DEVELOPING THE BASIS FOR EVALUATING ACCELERATED ROADBUILDING

Roads on the National Forests are a public investment, whether they are built with appropriated funds or by purchasers of Federal timber. In the latter case, the price paid for timber is less by the estimated roadbuilding cost than if the timber had been sold with the roads already in place.

If they are to contribute to maximizing public welfare, investments in National Forest roads should be economically efficient. In particular, roads should be built at

a rate that maximizes net returns, with costs and returns discounted at compound interest to make them comparable over time.

The following steps are required to rank alternative roadbuilding schedules by their economic desirability:

1. Specify the alternative rates of road construction to be examined, including the present rate.

2. Collect data on benefits over time for each alternative.

3. Collect data on costs over time for each alternative.

4. Subtract the annual benefits and costs for the present rate from the corresponding annual benefits and costs of each of the faster rates.

5. Calculate appropriate measures of investment worth for each accelerated rate of roadbuilding.

6. Rank the alternatives by each measure.

The optimum roadbuilding rate will be that rate having the highest positive present net worth at the appropriate discount rate. If no accelerated rate has a positive present net worth, the present roadbuilding rate will be defined as optimum. Rates of return and benefit cost ratios will be used as supplementary measures of economic efficiency.

Alternative Rates of Road Construction

At the beginning of 1966, there were 894 miles of road on the North Umpqua. Based on the assumption that 4 miles of permanent roads are required per section (640 acres) for complete access to timber stands,[3/] the planned road system for the North Umpqua is 3,109 miles, to serve 497,388 acres of commercial forest land (excluding the lodgepole pine type). Thus, 2,215 miles remained to be completed. At the then-current rate of roadbuilding of 75 miles per year, about 30 years would be required to complete the road system. This rate is used as the base against which the accelerated alternatives are measured.

ALLOWABLE CUT AND PATCH CUTTING LIMITATIONS

Only rates of roadbuilding faster than 75 miles per year are considered in this study. It is assumed that this rate is required to harvest the annual allowable cut of timber. Not to harvest the full allowable cut would violate Forest Service policies and reduce the economic return from the North Umpqua.

3/ *A planned road density of 4 miles per section is specified in the Timber Management Plan (TerBush and Kampmann 1961). At this density, on flat ground, a 50-acre square clearcut centered on a road would extend exactly halfway to a parallel, adjacent road.*

Although it would be possible to maintain the current allowable cut on the North Umpqua by building roads at less than 75 miles per year, doing so would prevent full application of the patch clearcutting system of timber harvest. This system has been adopted for silvicultural, fire protection, and esthetic reasons. As practiced on the North Umpqua, patch cutting harvests timber in 40- to 60-acre clearcut blocks. The result is a checkerboard pattern of timber harvest. This pattern requires building roads past some timber in order to reach the next cutting unit. As long as these "leave units" or uncut stands are bypassed, the allowable cut cannot be reached with a rate of road construction slower than 75 miles per year.

FOUR ACCELERATED RATES EVALUATED

Four alternatives to the present rate of roadbuilding are evaluated. They range from 1-1/3 to 6 times the present rate as shown in the following tabulation.

Miles per year	Years to complete system	Multiple of present rate
75	29.5	1.0
100	22.2	1.33
150	14.8	2.0
250	8.9	3.33
450	4.9	6.0

The time period over which benefits and costs are estimated must be long enough to include any differential effects of the five rates of roadbuilding. In one sense, each alternative is completed when the road system is finished. But, in another sense, an alternative is never completed because the effects of roadbuilding permanently change the character and management of a forest. For correct comparison of the five alternatives, benefits and costs for each must be estimated for at least 30 years, the time required to complete the road system at the slowest rate.

Costs and benefits after the first 30 years are assumed equal for each of the five roadbuilding plans. Although this assumption is not strictly correct, the importance of any differences beyond the 30th year is substantially reduced by discounting. For example, a 10-percent difference in net benefits between plans in the 31st year is only a 2-percent difference in present value at 5-percent interest or a 0.6-percent difference at 10-percent interest.

Uncertainty in predicting benefits and costs over time is another reason for cutting the comparison off at 30 years. Also, changes in prices or costs over time may obscure any differences that occur because of differing forest structures 30 years hence.

Determining Changes in Timber Harvesting Due to Accelerated Roadbuilding

This section quantifies changes in timber harvesting attributable to accelerated roadbuilding. Nontimber impacts, which are not readily measurable in dollars, are discussed separately.

For the most part, the volume harvested is limited by a Forest Service-established allowable cut. Because this cut is based upon all merchantable timber, without regard to whether it is presently accessible, changing the rate of road construction has little effect on the volume harvested.

Because the present rate of roadbuilding, 75 miles per year, is enough to harvest the annual allowable cut, the only increased volume attributable to advance roading is that not included in the present allowable cut base. As of 1966, the regulated allowable cut for the North Umpqua was 192.3 million board feet per year. A separately regulated cut of 9 million board feet was prescribed for landscape management areas primarily used for recreation. An unregulated cut of 5,700 board feet of dead timber was expected to be removed annually as "mortality salvage." This unregulated volume, which is neither a goal nor a limit, is the key variable in justifying accelerated road construction on an old-growth National Forest.

About 70 percent of total acreage of the North Umpqua is in the Douglas-fir type, with the remainder in the associated species type. Because volumes per acre and stumpage prices differ substantially between types, volumes are recorded for each.

Timber is removed from the North Umpqua by several methods of cutting. These include clearcutting, mortality salvage, thinning, and selective cutting in landscape management areas. A fifth cutting method, prelogging, is assumed possible as a result of accelerated roadbuilding.

SALVAGE CUTTING

The goal of salvage cutting is to remove dead or dying timber that would otherwise be lost to decay if left for the final harvest cut. In any old-growth forest, trees are continually dying, thereby adding to the volume of salvable dead timber.[4/] But, because of decay, the volume of salvable dead timber is constantly reduced. It is assumed that the rate of addition to salvable dead volume through mortality equals the rate of attrition through decay. Thus, the amount of salvable dead volume on the North Umpqua is assumed to remain constant in areas not under management.

The effect of accelerated roadbuilding is to open up areas for salvage of accumulated mortality earlier than would be possible at the present rate of construction. Because this volume is removed earlier, it has a higher present value. And the faster the accumulated mortality is harvested, the sooner a program of periodically salvaging current mortality can begin.

Salvage of accumulated mortality is possible in two locations: adjacent to roads and adjacent to clearcut perimeters. For all rates of road construction, roadside salvage is assumed to be carried out within 3 chains of each side of every mile of

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4/ *Salvable dead timber is defined as standing or down dead trees at least 11.0 inches in diameter breast high (d.b.h.) which contain at least 25 percent merchantable board-foot volume.*

new road,[5] or on 48 acres per mile, or 192 acres per section, or one-third of total acreage.[6] Salvage is assumed possible to a distance of 3 chains from clearcut perimeters on the 60 percent of acreage with slopes under 37.5 percent. For the average size clearcut of 50 acres, 17.4 acres of perimeter can be salvage cut, or 0.35 acre of perimeter for every acre of clearcut.

Salvage operations remove about 700 board feet[7] per acre of unregulated volume from roadside and clearcut perimeter acreage. Following initial salvage, roadside acreage can be resalvaged every 10 years for 75 percent of current mortality. Depending on forest type, volumes removed will be from 480 to 560 board feet per acre. Because salvage operations on the North Umpqua usually remove about 3,000 board feet per acre, considerable chargeable volume is removed at the same time. Removal of chargeable volumes in salvage operations introduces interdependency between clearcutting and salvage cutting. Faster rates of road construction result in a higher proportion of salvage to clearcutting.

PRELOGGING

Prelogging is the removal prior to clearcutting of small-diameter trees (up to 18 or 20 inches d.b.h.) that would otherwise be broken up and left as slash in a normal clearcut operation. It is assumed that no prelogging is possible at the current rate of road construction on the North Umpqua. Prelogging is generally done one or more years prior to clearcutting. The two operations are accomplished by separate sale contracts. Because 95 percent of the road mileage on the North Umpqua is constructed by timber purchasers, and because this road mileage is paid for by immediate clearcutting, there is no time between roadbuilding and clearcutting to award and administer a prelogging contract.

Thus, prelogging is projected to begin only after completion of the road system and therefore will begin earlier with the faster roadbuilding plans than with the present plan.

Prelogging is assumed to result in a 5-percent increase in total volume removed from clearcut units. Volume removed by prelogging is assumed to be 8,000 board feet per acre for both timber types. The following tabulation shows regulated and unregulated

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[5] *This figure is an average for all slopes and is based on Umpqua National Forest experience prior to 1966.*

[6] *This acreage is reduced slightly for roads passing through clearcuts.*

[7] *This figure is an average of accumulated mortality (merchantability class 8) for both timber types (Jones and TerBush 1961).*

volumes per acre by type:

	Douglas-fir type (M bd. ft.)	Associated species type (M bd. ft.)
Total volume (regulated if clearcut)	50.22	35.81
Unregulated prelogging (5 percent)	2.511	1.791
Regulated prelogging	5.489	6.209
Clearcut following prelogging	44.731	29.601

As shown above, prelogging and clearcutting are interrelated in terms of volume harvested. They are also interrelated in acreage, because acres prelogged one year are assumed to be clearcut the following year.

CLEARCUTTING

Clearcutting is the primary method of timber harvest on the North Umpqua, accounting for over 90 percent of the total cut in 1966.[8/] Only about 5 percent of clearcutting now occurs in the associated species type, but as the road network is extended, this percentage will increase. This increase is assumed to follow an arithmetic progression from the present level of cutting to a level that will allow the entire type to be harvested every 100 years, the length of the old-growth conversion period.

Another source of interdependency among clearcutting, salvage cutting, and prelogging results from clearing road rights-of-way. If roads are built faster, more timber is clearcut from rights-of-way and less from 50-acre blocks. Less clearcut perimeter is available for salvage, but more roadside acreage can be salvaged.

Because of the interdependency of cutting methods, an iterative procedure is used to calculate annual volumes by type and cutting method for each plan over a 30-year period. This calculation is described in detail in appendix A.

THINNING

Thinning produces only minor benefits for accelerated roadbuilding on the North Umpqua. As of 1966, thinning was planned in stands supporting 30- to 70-year-old timber on slopes less than 37-1/2 percent, or on only 5 percent of total acreage. Primarily because of low average site quality, volumes removable without lowering final harvest volume are quite low. These volumes are unregulated. In accord with the management plan (TerBush and Kampmann 1961), it is assumed that thinning will yield an average of 2,500 board feet per acre for both types, but each acre can be thinned only once during the plan period of 30 years. The only difference among roading plans is earlier recovery of thinning volumes by faster road construction.

[8/] *The shelterwood system is expected to replace some clearcutting on the North Umpqua in the future. But to simplify calculations, all final harvest (regeneration) cutting projected in this study is assumed to be clearcutting.*

SELECTIVE CUTTING

Nearly 45,000 acres of the North Umpqua are designated as landscape management areas or recreation zones. A separately regulated annual cut of 9 million board feet at 5,000 board feet per acre on 1,800 acres is set for these areas. Because this acreage is already accessible, selective cutting in recreation zones has no effect on the rate of roadbuilding.

TOTAL TIMBER VOLUMES

Annual timber volumes by cutting method and timber type are shown for each roadbuilding alternative in appendix B, tables 2 to 6. These data are summarized in figure 1, which shows average annual volume removed for each roading plan. The regulated allowable cut of 201.3 million board feet (including selective cutting) is exceeded by all five plans. As shown by the shape of the curve, the volume of unregulated material increases at a decreasing rate as the rate of road construction increases. The average annual volume for the 450-mile rate is 5.6 percent greater than for the present 75-mile rate.

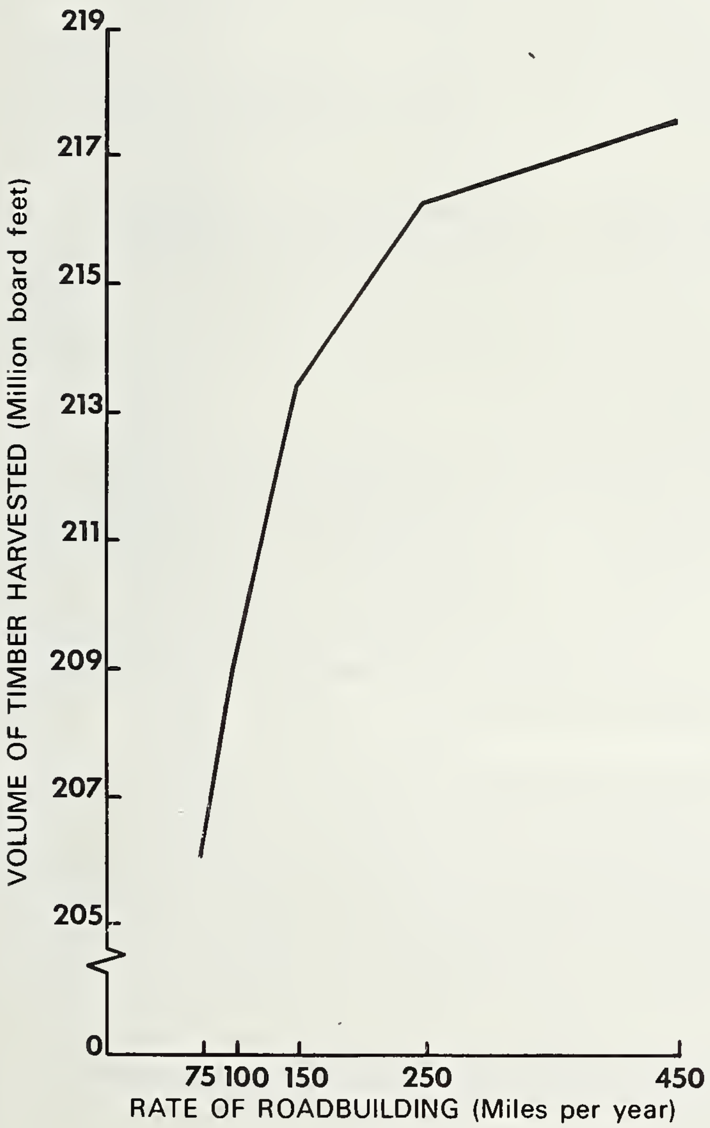

Figure 1.--Average annual volume of timber from 1966 to 1995 for five rates of roadbuilding.

Percentages of average annual volume by cutting method vary among roadbuilding alternatives, as shown in the following tabulation:

Cutting method:	75 miles per year	450 miles per year
Clearcutting	89	66
Salvage cutting	6	18
Thinning	1	1
Selective cutting	4	4
Prelogging	0	11
Total	100	100

These differences are a maximum for the five alternatives. Percent of annual volume by cutting method for the other rates of roadbuilding falls between these two extremes. As shown, increasing the rate of road construction causes a shift from clearcutting to salvage cutting and prelogging.

STUMPAGE PRICES

The following are the stumpage prices assumed in this study for all rates of roadbuilding, every year, in dollars per thousand board feet:

	Douglas-fir type		*Associated species type*	
	Before road completion	After road completion	Before road completion	After road completion
Clearcutting, normal stands	36.71	--	19.37	--
Clearcutting, prelogged stands	--	47.31	--	30.49
Salvage cutting	39.73	40.85	19.29	20.41
Prelogging	--	22.18	--	11.62
Thinning	29.57	35.40	15.49	21.35
Selective cutting	40.85	40.85	20.41	20.41

Multiplying timber volumes by these stumpage prices yields annual benefits for each roadbuilding alternative, as shown in appendix B, table 7.

Prices for clearcutting of normal (not prelogged) stands and for salvage cutting were obtained as an average of actual prices paid for Forest Service timber on the North Umpqua unit during the 2-1/2-year period, January 1964 to June 1966.[9] Prices paid for thinning volumes are based on data from the Willamette National Forest, located immediately to the north of the Umpqua. Prices for prelogging volumes are based on sales on the Willamette and the Mount Hood (immediately north of the Willamette)

[9] *Pacific Northwest Region, USDA Forest Service, National Forest advertised timber sales, Region 6 (mimeographed report, quarterly).*

National Forests. Prices for selective cutting were assumed equal to salvage cutting prices with the road system completed. The prices for clearcutting of prelogged stands are estimated so that the value of timber removed by clearcutting plus the value of regulated prelogging volume equals the value of timber clearcut without prelogging. Consequently, the only benefit of prelogging is the 5-percent volume increase in unregulated material valued at the prelogging stumpage price.

Prices shown for the Douglas-fir type are those reported for the Douglas-fir species. An average of all other species prices is shown as the price for the associated species type.

The prices after road completion represent the addition of road development costs to the prices reported before road completion. They are "high bid" prices rather than "statistical high bid" prices. [10] Forest Service timber is appraised as if access roads are already in place, and bids are received on the same basis. Estimated road construction cost per thousand board feet is then deducted from the high bid price to find the price which the high bidder actually pays. This price is the statistical high bid. When the road system has been completed, there will be no road development costs to subtract. Therefore, present high bid prices are a good estimate of actual prices following road system completion. Until the system is completed, the net payment received by the Forest Service is measured by statistical high bid prices. The increase in stumpage prices received by the Forest Service following road system completion represents the recovery of funds invested in roads.

Present stumpage prices are projected over the 30-year investment period. Because prices are subject to uncertainty, the effects on rates of return of certain price changes are discussed in a sensitivity analysis. These changes include 10- and 20-percent increases and decreases in the prices shown in the above tabulation. Each of these changed price levels is projected over the entire 30-year period.

There are two other types of price changes that might be examined. The first is a change in stumpage prices as the rate of roadbuilding increases. If faster roadbuilding produces more timber and the demand for timber is less than perfectly elastic, the price of timber will tend to fall as the rate of roadbuilding is increased. However, as shown in figure 1, average annual timber volume increased by only 11.5 million board feet or 5.6 percent from the slowest to the fastest roadbuilding alternative. This increase represents only 0.8 percent of the total cut in Douglas County in 1966. The effect on prices of this small increase in volume is believed negligible.

Stumpage prices may change over time even if they do not vary among roadbuilding plans. And they may vary relative to roadbuilding costs. To test the effect of such changes on the relative merit of alternative roading plans, 1- and 3-percent annual increases in stumpage prices, total costs, and both prices and costs together are included in the sensitivity analysis.

[10] *See footnote 9.*

Cost of Timber Access Roads

The only costs included in the present net worth and related calculations are for construction and maintenance of roads necessary to harvest timber. Additional roading costs to accommodate nontimber traffic or to protect other resources are discussed separately.

The road system to be completed was earlier defined as 2,215 miles, with the only difference among roading plans being the timing of construction of this mileage. Therefore, the only extra costs of accelerated roadbuilding are interest and maintenance from the time roads are completed under an accelerated plan to the time when they would be completed by the present plan. This conclusion assumes that road costs will not change over time from their present level, and that they will not vary with mileage constructed per year. If costs rise in the future, accelerated roadbuilding will lower the initial construction cost relative to the present plan, and vice versa. The effect of such a change is measured by including 1- and 3-percent annual cost increases in the sensitivity analysis. In addition, changes in the level of road costs are examined for their effects on the ranking of roadbuilding alternatives.

An average construction cost of $30,000 per mile is used for all roads. This figure is a weighted average of current (1966) costs for 2.69 miles per section of "U" roads[11] at $39,750 per mile and 1.31 miles per section of temporary roads at $10,000 per mile.[12]

Normal road maintenance costs for the present rate of road construction are accounted for in determining appraised stumpage prices. For the faster rates, road maintenance on the additional mileage is added at $73 per mile per year. Additional mileage is calculated each year as cumulative mileage with accelerated roadbuilding minus cumulative mileage at 75 miles per year. For each alternative, this mileage reaches a maximum in the year the road system is completed and then decreases to zero in the 30th year, when each alternative has completed the same total mileage.

Annual road construction and maintenance costs for each roadbuilding alternative are shown in appendix B, table 8.

EVALUATING ACCELERATED RATES OF ROAD CONSTRUCTION

In a determination of whether roads should be built faster, the relevant benefits and costs are differences between the accelerated rates and the current rate of construction. These are calculated by subtracting current rate values in tables 7 and 8, appendix B, from the respective values for each accelerated rate.

11/ *Land use or "U" roads are the lowest standard of Forest Service permanent roads.*

12/ *Cost data provided by Division of Engineering, Pacific Northwest Region, USDA Forest Service.*

Not all of these benefit and cost differences are positive. In fact, cost differences for accelerated roadbuilding plans are negative for all years following projected completion of the road system. This result occurs because the constant annual construction cost of the 75-mile rate is subtracted from costs that are higher during the early years and very low during the later years of the other plans.

Accelerated Roadbuilding for Timber Management Not Economically Justified

Given the previously developed benefits and costs, rates of return on the required additional investments in accelerated roadbuilding are as follows:

Rate of roadbuilding	Rate of return
(Miles per year)	(Percent)
100	3.0
150	3.6
250	3.4
450	2.9

From this listing it can be decided which accelerated rates of roadbuilding would be desirable investments. For example, doubling the rate of construction from the current 75 miles per year to 150 miles per year would be a profitable investment if dollars were available to the Federal Government at a cost of less than 3.6 percent, that is, if the appropriate discount rate were less than 3.6 percent. Unfortunately, the minimum rate that should be considered for federal investments is probably around 5 percent (U. S. Congress, Joint Economic Committee 1968; USDA Forest Service 1969), and about 8 percent may well be a better estimate of the true cost of federal money. In short, at any reasonable discount rate, all of the accelerated roadbuilding alternatives would lose money. This conclusion is illustrated in figure 2: at any discount rate greater than 3.6 percent for any accelerated rate of construction, discounted costs always exceed discounted benefits, and present net worths are negative. Similarly, benefit-cost ratios are less than 1.0; this also indicates that accelerated roadbuilding is a poor investment.

Sensitivity Analyses of Evaluation

To reach this conclusion, a number of specific assumptions were made. Here these assumptions are varied to determine if they are critical to the conclusion.

An important benefit of faster roadbuilding is the earlier removal of both salvable dead timber and current mortality. In 1966, roadside mortality salvage was possible on only 48 acres per mile of road, and the above results are based on this value. By 1971, however, roadside salvage was accomplished on 120 acres per mile, 2-1/2 times the previous amount. Although this change would increase projected average annual timber harvests by from 1 to 4 percent, the effect on the economic desirability of accelerated roadbuilding is negligible: rates of return increase only by about one-tenth of 1 percent for the four accelerated alternatives.

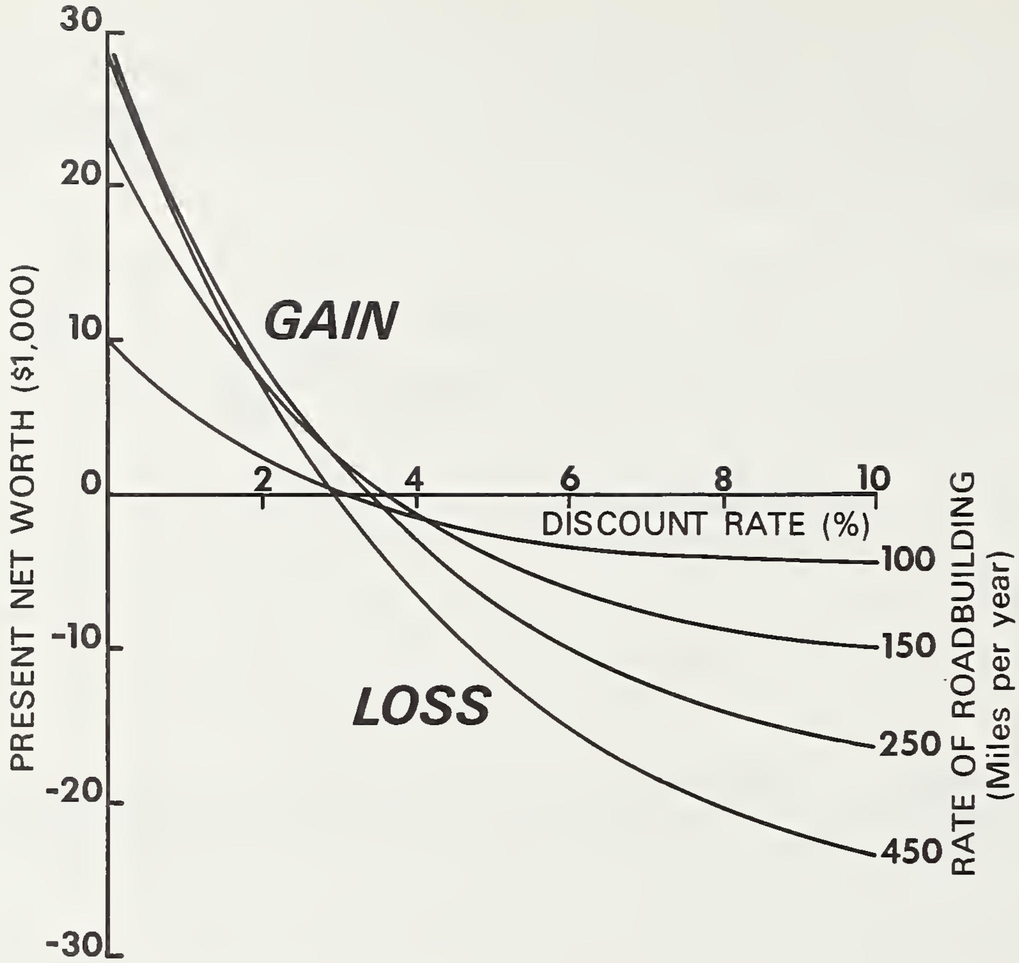

Figure 2.--Present net worth of four accelerated rates of roadbuilding at discount rates from 0 to 10 percent.

The sensitivity of the measures of investment worth was tested for increases and decreases of 10 and 20 percent in the levels of stumpage prices, construction costs, and maintenance costs. Also tested were the effects of 1- and 3-percent annual increases in stumpage prices, total costs, and both prices and costs together. Resulting changes in rates of return are shown in table 1.

A 20-percent increase in the level of stumpage prices or a 20-percent decrease in construction costs raised the rate of return of the 150-mile-per-year alternative to slightly over 4 percent, not a particularly attractive earning rate. Other tested changes in price and cost levels had even less effect.

Annual increases in prices and costs had a substantial effect on the measures of investment worth. Small annual increases in stumpage prices raised the rates of return of the accelerated roadbuilding alternatives by placing a higher value on the additional timber they generate in the first few years of construction. (Only if the rate of price increases exceeded the discount rate would the relatively slow harvesting called for by the present roadbuilding program be favored.) Raising costs over time also increased the desirability of the faster roadbuilding rates relative to the current rate.

Table 1.--Rates of return for four alternative roadbuilding plans for changes in stumpage prices, construction costs, and maintenance costs

Change in			Rate of roadbuilding (miles per year)			
Stumpage prices	Construction costs	Maintenance costs	100	150	250	450
--Percent--			--Percent--			
0	0	0	3.0	3.6	3.4	2.9
+10	0	0	3.3	3.9	3.7	3.2
+20	0	0	3.6	4.2	3.9	3.4
-10	0	0	2.8	3.3	3.1	2.6
-20	0	0	2.6	3.0	2.8	2.4
0	+10	0	2.8	3.4	3.1	2.7
0	+20	0	2.7	3.1	2.9	2.5
0	-10	0	3.3	3.9	3.7	3.2
0	-20	0	3.6	4.3	4.0	3.5
0	0	+10	3.0	3.6	3.4	2.9
0	0	+20	3.0	3.6	3.3	2.9
0	0	-10	3.1	3.6	3.4	2.9
0	0	-20	3.1	3.7	3.4	2.9
+10	+10	+10	3.0	3.6	3.4	2.9
+20	+20	+20	3.0	3.6	3.4	2.9
-10	-10	-10	3.0	3.6	3.4	2.9
-20	-20	-20	3.0	3.6	3.4	2.9
+1/year	0	0	3.7	4.2	3.9	3.4
+3/year	0	0	5.4	5.8	5.2	4.4
0	+1/year	+1/year	3.5	4.0	3.9	3.5
0	+3/year	+3/year	4.6	5.1	5.1	4.9
+1/year	+1/year	+1/year	4.1	4.6	4.4	3.9
+3/year	+3/year	+3/year	6.1	6.7	6.5	6.0

Although higher present net worths, benefit-cost ratios, and rates of return appear to be a paradoxical result of increasing costs, these values are all measured relative to those for the present rate of road construction. If per-mile costs rise as a function of time, the earlier the road system is completed, the less it will cost.

The case in which prices and costs rise at the same rate is particularly important, representing inflation. Combining the separate effects of rising prices and rising costs yields rates of return of up to 6.7 percent.13/

13/ *The propriety of the Federal Government relying on inflation to justify any investments is questioned by McKean (1958).*

Nontimber Benefits and Costs Reduce Desirability of Accelerated Roadbuilding

The preceding section is limited to the economic desirability of accelerated roadbuilding for the management of timber only. Because most nontimber resources lack well-established market prices, their impact on road scheduling decisions is hard to evaluate. Nevertheless, the following tabulation summarizes the expected direction of effect of accelerated roadbuilding on several nontimber resources and activities.

Resource or activity	Probable effect of accelerated roadbuilding
Fisheries	Negative
Soil and water	Negative
Wildlife	Uncertain
Recreation	Uncertain
Fire protection	Uncertain
Administration	Positive

FISHERIES, SOIL, AND WATER RESOURCES ADVERSELY AFFECTED

Accelerated roadbuilding may have damaging effects on fisheries and on soil and water resources unless preventive measures are taken (USDA Forest Service 1969). Increasing annual road construction may increase mass soil movement, erosion, and sediment load in streams. Sediment causes direct injury to fish by abrasion. In addition, it reduces the normal catch of fish by increasing water turbidity, destroys spawning beds by siltation, reduces the amount of available food, and disrupts normal migration of fish.

Although sediment is harmful to fish, most damage can be prevented by known methods of control, such as drainage and filtration, road surface compaction, protection of fill slopes from erosion, and hauling of excess earth away from streams to stable locations. The cost of holding sedimentation to the level experienced at the current rate of roadbuilding in 1966 is one measure of the impact of accelerated roadbuilding. This cost can be expressed per mile of road and included in net worth and earning rate calculations. Doing so will reduce the economic desirability of faster roadbuilding.

If the current level of sedimentation (or any other adverse effect of road construction) is unacceptably high, costs may be further increased, thereby reducing the desirability of accelerated roadbuilding still more. For example, roadbuilding costs on western Oregon National Forests have increased from $30,000 per mile in 1966 to $50,000 to $80,000 per mile in 1971. Much of this increase is for environmental protection. In an extrapolation from table 1, a doubling of construction costs would reduce rates of return for accelerated roadbuilding by one-half to two-thirds. Thus, the desirability of accelerated roadbuilding is drastically reduced when impacts on fisheries, soil, and water resources are considered.

WILDLIFE, RECREATION, FIRE PROTECTION EFFECTS UNCERTAIN

Accelerated roadbuilding may have both positive and negative effects on wildlife and recreation resources and on fire protection. But the overall effect on each is uncertain.

An example of a negative effect on wildlife is the reduction in deer browse associated with the shift away from clearcutting in favor of salvage cutting and prelogging. Although partial cutting opens up the forest canopy and allows more undergrowth to develop, this increase is offset by the reduction in clearcut acreage, since clearcuts provide up to 10 times as much browse per acre as partially cut stands.

The impact of accelerated roadbuilding on recreation may be positive or negative depending on one's point of view. Building roads faster will have beneficial effects for roadside campers and adverse effects for wilderness enthusiasts. Costs to the agency for road and recreation site maintenance may go up as fast as benefits to users. And accelerated roadbuilding may simply shift benefits or costs from one location to another. Because most of the lakes, main streams, and outstanding scenic areas of the North Umpqua are already accessible, net recreation benefits attributable to faster road system completion here should be minor.

Earlier access to timber stands through accelerated road construction would benefit fire suppression efforts. With a completed road system, fires could be extinguished at lower cost and with less loss. However, faster road construction may increase the risk that fires will start. If recreational use is dispersed over a broader area or to less developed sites, the risk of man-caused fires will grow. Thus, protection costs may increase in direct relation to the rate of road construction. Lower suppression cost per fire may be balanced by more fires or by higher prevention costs.

ADMINISTRATIVE COSTS LOWERED

Faster completion of the road system would have definite administrative and management advantages. For example, periodic forest inventories could be accomplished more efficiently. Earlier road construction would allow the forest manager to take advantage of opportunities to harvest high-value species or products as market prices fluctuate. Insect and disease protection and the salvage of catastrophic mortality following windstorms or insect epidemics would also benefit. And it is possible that faster roadbuilding, not tied to timber harvest, would allow a more logical and more efficient scheduling of the construction of various road segments.

CONCLUSIONS

Accelerated roadbuilding does not appear economically justified on the North Umpqua, neither for timber access nor for multiple use management. Although this conclusion is based on conditions as of 1966, changes in harvesting technology, stumpage prices, and roadbuilding costs since that time only strengthen this finding.

The primary timber benefits from accelerated roadbuilding on the North Umpqua

arise from salvage cutting and prelogging. But amounts of salvable dead volume and current mortality per acre are fairly low, even though the forest is overmature, and average site quality is quite low. Higher site forests might be better candidates for accelerated roadbuilding.

The estimated 5-percent increase in volume by prelogging may be conservative for some forest areas. On the other hand, prelogging is possible only where clearcutting is the method of final timber harvest. On forests managed selectively, there is no need nor opportunity for prelogging.

Thinning will be an important benefit of faster roadbuilding on relatively few forests. Generally, young-growth forests where thinning would be practiced already have a road system in place. An exception is young-growth stands established following fires or blowdowns. These areas may benefit from thinning but may not yet be accessible. However, Schallau's (1970) study of young-growth timber on high-site land showed negative rates of return when thinning was the only method of timber harvest.

The major cost of accelerated roadbuilding is interest on the road construction expenditure. Total construction cost in current dollars is identical for the five plans in this study, and differences in maintenance costs are minor. But the interest borne by the fastest roading plan is enormous compared with that for the slowest plan. For even moderate interest rates, this difference overwhelms the relatively modest difference in benefits between these plans.

The findings of this study, coupled with the "Douglas-fir Supply Study" (USDA Forest Service 1969) and Schallau's (1970) study, suggest that accelerated roadbuilding may not be an attractive investment opportunity for National Forests in the Douglas-fir region.

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APPENDIX A

Calculation of Annual Timber Volumes

Clearcutting, salvage cutting, and prelogging are interrelated. Annual volumes of timber removed by each cutting method must be determined simultaneously.

Given factors include the annual allowable cut (regulated cut), annual road mileage constructed by forest type, annual acreage clearcut in the associated species type, and volumes per acre by forest type by all cutting methods.

Calculating volumes harvested by cutting method before the road system is completed (no prelogging) requires the following steps:

1. Calculate volume clearcut from road rights-of-way, by timber type.
   a. Miles of road per year by type (given).
   b. Multiply by 4 acres per mile.
   c. Multiply by volume per acre by type (given).

2. Estimate road mileage passing through clearcut units and therefore not available for salvage.
   a. Estimate total acreage clearcut in blocks.
   b. Divide by 50 acres per block.
   c. Multiply by 0.28 mile of road per block, the distance across a 50-acre square block.

3. Calculate regulated and unregulated roadside salvage volume.
   a. Mileage available (step 1a minus step 2).
   b. Multiply by 48 acres per mile.
   c. Multiply by regulated and unregulated volumes per acre by type (given).

4. Calculate associated species block clearcut volume.
   a. Acreage clearcut in associated species type (given).
   b. Subtract acreage in type clearcut in road right-of-way (step 1b).
   c. Multiply by volume per acre (given).

5. Calculate associated species regulated and unregulated clearcut perimeter salvage volumes.
   a. Multiply acreage clearcut (step 4a) by 0.35 acre of perimeter per acre clearcut.
   b. Multiply by regulated and unregulated volumes per acre (given).

6. Calculate Douglas-fir block clearcut acreage.
   a. Total annual allowable cut (given).
   b. Subtract right-of-way clearcutting (step 1), associated species block clearcutting (step 4), the regulated portions of roadside salvage (step 3), and associated species clearcut perimeter salvage (step 5).
   c. Divide by a weighted average of Douglas-fir clearcut and regulated perimeter salvage volumes per clearcut acre (calculated from given quantities).

7. Compare Douglas-fir block clearcut acreage (step 6) with estimate (step 2a).
   a. If acreages are not equal to the nearest 100 acres, replace estimate (step 2a) with calculated acreage (step 6) and repeat steps 2 through 6.
   b. When acreages are equal continue to step 8.

8. Calculate Douglas-fir block clearcut volume.
   a. Acreage clearcut in blocks (step 6).
   b. Multiply by volume per acre (given).

9. Calculate Douglas-fir clearcut perimeter salvage volume.
   a. Multiply acreage clearcut (step 6) by 0.35 acre of perimeter per clearcut acre.
   b. Multiply by regulated and unregulated volumes per acre (given).

10. Repeat steps 1 through 9 for each year of each plan during which roads are built.

When the road system has been completed, prelogging of clearcut units and resalvage of roadside acreage begin. The following steps are required to calculate volumes harvested by forest type and cutting method:

1. Calculate regulated and unregulated roadside resalvage volume by type.
   a. Total road mileage by type (given).
   b. Multiply by 48 acres per mile.
   c. Subtract acres clearcut in roadside salvage zone. (Average for life of plan is about 10 percent of total acreage.)
   d. Multiply by 10 percent. (Each acre is resalvaged every 10 years.)
   e. Multiply by regulated and unregulated volumes per acre by type (given).

2. Calculate associated species clearcut volume.
   a. Acreage clearcut in associated species type (given).
   b. Multiply by volume per acre (given).

3. Calculate associated species regulated and unregulated clearcut perimeter salvage volumes.
   a. Multiply acreage clearcut (step 2a) by 0.35 acre of perimeter per acre of clearcut.
   b. Multiply by regulated and unregulated volumes per acre (given).

4. Calculate associated species regulated and unregulated prelogging volume.
   a. Acres prelogged are those acres to be clearcut the following year (given).
   b. Multiply by regulated and unregulated volumes per acre (given).

5. Calculate regulated volume to be harvested by clearcutting, salvage cutting, and prelogging in the Douglas-fir type.
   a. Total annual allowable cut (given).
   b. Subtract regulated portion of roadside resalvage (step 1), and associated species clearcutting (step 2), perimeter salvage (step 3), and prelogging (step 4).

6. Allocate regulated Douglas-fir volume to clearcutting, salvage cutting, and prelogging, using the following set of equations:

$$\frac{DVOL_t - (PAC_t)(PVOL/AC)}{CSVOL/AC} = CAC_t$$

$$PAC_t = CAC_{t+1}$$

$$\frac{DVOL_{t+1} - (CAC_{t+1})(CSVOL/AC)}{PVOL/AC} = PAC_{t+1}$$

$$PAC_{t+1} = CAC_{t+2}$$

where:

$DVOL_t$ = Douglas-fir volume cut in year t (step 5).
PAC_t = Acrès prelogged in year t (estimated).
$PVOL/AC$ = Regulated prelogging volume per acre.
$CSVOL/AC$ = Weighted average of clearcut volume and regulated perimeter salvage volume per clearcut acre (calculated from given quantities).
CAC_t = Acres clearcut in year t.

a. Choose PAC_t by iteration such that

$$CAC_{t+1} - CAC_t = CAC_{t+2} - CAC_{t+1}$$

That is, the difference in clearcut acreage is constant from year to year.

b. Calculate clearcut volume as acres (from step 6a) times volume per acre (given).
c. Calculate perimeter salvage volume as acres clearcut (step 6a) times 0.35 acre salvaged times regulated and unregulated volumes per acre (given).
d. Calculate volume prelogged as acres (from equations of step 6 and step 6a) times regulated and unregulated volumes per acre (given).
e. Check: The sum of steps 6a, 6b, 6c, and 6d should equal step 5.

7. The difference found in step 6a will be a constant for the remaining years of each plan. Douglas-fir clearcut and prelogged acreage can be calculated by adding this difference to the previous year's total.

8. Repeat steps 1 through 7 for each plan.

APPENDIX B

Tables

Table 2.--Annual timber volumes by cutting method and timber type for roadbuilding at 75 miles per year

(In thousand board feet)

Year	Clearcutting		Salvage		Prelogging		Thinning		Total[1]		
	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	All
1966	176,793	6,647	10,884	612	0	0	2,308	1,025	194,985	12,284	207,269
1967	175,848	7,586	10,599	906	0	0	2,308	1,025	193,755	13,517	207,272
1968	174,912	8,516	10,314	1,197	0	0	2,308	1,025	192,534	14,738	207,272
1969	173,967	9,455	10,167	1,353	0	0	2,308	1,025	191,442	15,833	207,275
1970	173,023	10,394	9,822	1,644	0	0	2,308	1,025	190,153	17,063	207,216
1971	172,087	11,324	9,600	1,935	0	0	2,308	1,025	188,995	18,284	207,279
1972	171,142	12,263	9,315	2,226	0	0	2,308	1,025	187,765	19,514	207,279
1973	170,207	13,193	9,030	2,520	0	0	2,308	1,025	186,545	20,738	207,283
1974	169,261	14,132	8,886	2,673	0	0	2,308	1,025	185,455	21,830	207,285
1975	168,325	15,062	8,601	2,964	0	0	2,308	1,025	184,234	23,051	207,285
1976	167,380	16,001	8,316	3,258	0	0	568	932	181,264	24,191	205,455
1977	166,445	16,931	8,028	3,552	0	0	568	932	180,041	25,415	205,456
1978	165,500	17,870	7,746	3,840	0	0	568	932	178,814	26,642	205,456
1979	164,564	18,800	7,461	4,134	0	0	568	932	177,593	27,866	205,459
1980	163,619	19,739	7,317	4,287	0	0	568	932	176,504	28,958	205,462
1981	162,683	20,669	7,032	4,578	0	0	568	932	175,283	30,179	205,462
1982	161,738	21,608	6,747	4,872	0	0	568	932	174,053	31,412	205,465
1983	160,802	22,538	6,465	5,160	0	0	568	932	172,835	32,630	205,465
1984	159,857	23,478	6,177	5,457	0	0	568	932	171,602	33,867	205,469
1985	158,922	24,407	6,033	5,607	0	0	568	932	170,523	34,946	205,469
1986	157,977	25,346	5,748	5,901	0	0	568	932	169,293	36,179	205,472
1987	157,041	26,276	5,463	6,192	0	0	568	932	168,072	37,400	205,472
1988	156,096	27,215	5,178	6,486	0	0	568	932	166,842	38,633	205,475
1989	155,159	28,146	4,893	6,777	0	0	568	932	165,620	39,855	205,475
1990	154,215	29,084	4,749	6,930	0	0	568	932	164,532	40,946	205,478
1991	153,280	30,014	4,323	7,362	0	0	568	932	163,171	42,308	205,479
1992	152,335	30,953	4,179	7,512	0	0	568	932	162,082	43,397	205,479
1993	151,389	31,893	3,894	7,806	0	0	568	932	160,851	44,631	205,482
1994	150,454	32,822	3,612	8,097	0	0	568	932	159,634	45,851	205,485
1995	149,508	33,762	3,360	8,358	0	0	568	932	158,436	47,052	205,488

1/ Includes 5 million board feet in Douglas-fir and 4 million board feet in associated species from selected cutting.

Table 3.--Annual timber volumes by cutting method and timber type for roadbuilding at 100 miles per year

(In thousand board feet)

Year	Clearcutting		Salvage		Prelogging		Thinning		Total[1/]		
	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	All
1966	174,164	6,625	14,046	888	0	0	2,510	1,355	195,720	12,868	208,588
1967	173,227	7,556	13,623	1,320	0	0	2,510	1,355	194,360	14,231	208,591
1968	172,291	8,487	13,200	1,752	0	0	2,510	1,355	193,001	15,594	208,595
1969	171,354	9,418	12,621	2,340	0	0	2,510	1,355	191,485	17,113	208,598
1970	170,418	10,349	12,192	2,775	0	0	2,510	1,355	190,120	18,479	208,599
1971	169,469	11,280	11,769	3,204	0	0	2,510	1,355	188,748	19,839	208,587
1972	168,543	12,211	11,346	3,636	0	0	2,510	1,355	187,399	21,202	208,601
1973	167,607	13,142	10,905	4,083	0	0	2,510	1,355	186,022	22,580	208,602
1974	166,669	14,073	10,341	4,656	0	0	2,510	1,355	184,520	24,084	208,604
1975	165,732	15,004	9,918	5,088	0	0	2,510	1,355	183,160	25,447	208,607
1976	164,795	15,935	9,492	5,523	0	0	770	1,263	180,057	26,721	206,778
1977	163,858	16,867	9,051	5.967	0	0	770	1,263	178,679	28,097	206,776
1978	162,920	17,798	8,628	6,399	0	0	770	1,263	177,318	29,460	206,778
1979	161,983	18,729	8,064	6,972	0	0	770	1,263	175,817	30,964	206,781
1980	161,047	19,660	7,641	7,404	0	0	770	1,263	174,458	32,327	206,785
1981	160,109	20,591	7,200	7,851	0	0	770	1,263	173,079	33,705	206,784
1982	159,172	21,522	6,777	8,283	0	0	770	1,263	171,719	35,068	206,787
1983	158,236	22,453	6,351	8,715	0	0	770	1,263	170,357	36,431	206,788
1984	157,299	23,384	5,772	9,303	0	0	770	1,263	168,841	37,950	206,791
1985	156,361	24,315	5,349	9,735	0	0	770	1,263	167,480	39,313	206,793
1986	155,425	25,246	4,923	10,167	0	0	770	1,263	166,118	40,676	206,794
1987	154,488	26,177	4,500	10,599	0	0	770	1,263	164,758	42,039	206,797
1988	125,947	27,108	3,171	2,247	21,501	6,264	108	177	155,727	39,796	195,523
1989	120,219	23,178	25,610	9,771	21,352	6,472	0	0	172,181	43,421	215,602
1990	119,385	23,947	25,591	9,798	21,202	6,680	0	0	171,178	44,425	215,603
1991	118,550	24,717	25,571	9,825	21,053	6,888	0	0	170,174	45,430	215,604
1992	117,715	25,486	25,552	9,852	20,904	7,096	0	0	169,171	46,434	215,605
1993	116,881	26,256	25,532	9,879	20,754	7,304	0	0	168,167	47,439	215,606
1994	116,046	27,026	25,512	9,909	20,605	7,512	0	0	167,163	48,447	215,610
1995	115,211	27,795	25,492	9,936	20,456	7,720	0	0	166,159	49,451	215,610

[1/] Includes 5 million board feet in Douglas-fir and 4 million board feet in associated species from selected cutting.

Table 4.--Annual timber volumes by cutting method and timber type for roadbuilding at 150 miles per year

(In thousand board feet)

Year	Clearcutting		Salvage		Prelogging		Thinning		Total[1/]		
	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	All
1966	168,755	6,624	20,436	1,521	0	0	2,895	1,985	197,086	14,130	211,216
1967	167,817	7,556	19,479	2,484	0	0	2,895	1,985	195,191	16,025	211,216
1968	166,880	8,487	18,528	3,444	0	0	2,895	1,985	193,303	17,916	211,219
1969	165,943	9,418	17,445	4,533	0	0	2,895	1,985	191,283	19,936	211,219
1970	165,005	10,349	16,479	5,511	0	0	2,895	1,985	189,379	21,845	211,224
1971	164,069	11,280	15,522	6,474	0	0	2,895	1,985	187,486	23,739	211,225
1972	163,132	12,211	14,565	7,437	0	0	2,895	1,985	185,592	25,633	211,225
1973	162,195	13,142	13,596	8,412	0	0	2,895	1,985	183,686	27,539	211,225
1974	161,258	14,073	12,489	9,528	0	0	2,895	1,985	181,642	29,586	211,228
1975	160,321	15,004	11,532	10,494	0	0	2,895	1,985	179,748	31,483	211,231
1976	159,384	15,935	10,566	11,469	0	0	1,155	1,893	176,101	33,297	209,402
1977	158,446	16,867	9,594	12,447	0	0	1,155	1,893	174,195	35,207	209,402
1978	157,510	17,798	8,625	13,425	0	0	1,155	1,893	172,290	37,116	209,406
1979	156,572	18,729	7,503	14,553	0	0	835	1,453	169,960	38,735	208,695
1980	140,075	19,660	5,025	12,456	22,624	4,600	0	0	172,724	40,716	213,440
1981	126,501	17,021	26,144	9,705	22,475	4,808	0	0	180,120	35,534	213,654
1982	126,668	17,790	26,124	9,732	22,327	5,016	0	0	180,119	36,538	216,657
1983	124,835	18,560	26,105	9,759	22,177	5,224	0	0	178,117	37,543	215,660
1984	124,001	19,329	26,085	9,789	22,028	5,432	0	0	177,114	38,550	215,664
1985	123,168	20,099	26,066	9,816	21,879	5,640	0	0	176,113	39,555	215,668
1986	122,335	20,869	26,046	9,843	21,731	5,848	0	0	175,112	40,560	215,672
1987	121,501	21,638	26,027	9,870	21,581	6,056	0	0	174,109	41,564	215,673
1988	120,668	22,408	26,007	9,897	21,432	6,264	0	0	173,107	42,569	215,676
1989	119,835	23,178	25,988	9,924	21,283	6,472	0	0	172,106	43,574	215,680
1990	119,001	23,947	25,969	9,951	21,134	6,680	0	0	171,104	44,578	215,682
1991	118,168	24,717	25,949	9,978	20,985	6,888	0	0	170,102	45,583	215,685
1992	117,335	25,486	25,930	10,005	20,836	7,096	0	0	169,101	46,587	215,688
1993	116,501	26,256	25,910	10,032	20,687	7,304	0	0	168,098	47,592	215,690
1994	115,668	27,026	25,890	10,062	20,538	7,512	0	0	167,096	48,600	215,696
1995	114,835	27,795	25,871	10,089	20,389	7,720	0	0	166,095	49,604	215,699

[1/] Includes 5 million board feet in Douglas-fir and 4 million board feet in associated species from selected cutting.

Table 5.--Annual timber volumes by cutting method and timber type for roadbuilding at 250 miles per year

(In thousand board feet)

Year	Clearcutting		Salvage		Prelogging		Thinning		Total[1/]		
	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	All
1966	160,275	4,297	31,659	4,320	0	0	3,662	3,520	200,596	16,137	216,733
1967	157,680	6,876	29,088	6,912	0	0	3,662	3,520	195,430	21,308	216,738
1968	155,085	9,454	26,517	9,504	0	0	3,662	3,520	190,264	26,478	216,742
1969	152,347	12,175	23,805	12,240	0	0	3,662	3,520	184,814	31,935	216,749
1970	149,752	14,754	21,234	14,832	0	0	3,662	3,520	179,648	37,106	216,754
1971	147,157	17,332	18,663	17,424	0	0	3,662	3,520	174,482	42,276	216,758
1972	144,418	20,054	15,948	20,160	0	0	3,662	3,520	169,028	47,734	216,762
1973	141,823	22,632	13,380	22,752	0	0	3,662	3,520	163,865	52,904	216,769
1974	125,588	23,348	12,576	18,684	22,006	5,376	3,395	2,805	168,565	54,213	222,778
1975	123,047	19,892	26,412	9,942	21,892	5,536	1,740	92	178,091	39,462	217,553
1976	122,406	20,484	26,397	9,963	21,777	5,696	0	0	175,580	40,143	215,723
1977	121,764	21,076	26,382	9,984	21,662	5,856	0	0	174,808	40,916	215,724
1978	121,123	21,668	26,367	10,005	21,547	6,016	0	0	174,037	41,689	215,726
1979	120,482	22,260	26,352	10,026	21,433	6,176	0	0	173,267	42,462	215,729
1980	119,840	22,852	26,331	10,047	21,318	6,336	0	0	172,489	42,435	214,924
1981	119,199	23,444	26,322	10,068	21,203	6,496	0	0	171,724	44,008	215,732
1982	118,557	24,036	26,307	10,089	21,089	6,656	0	0	170,953	44,781	215,734
1983	117,916	24,628	26,292	10,110	20,974	6,816	0	0	170,182	45,554	215,736
1984	117,274	25,220	26,277	10,131	20,859	6,976	0	0	169,410	46,327	215,737
1985	116,633	25,812	26,262	10,152	20,744	7,136	0	0	168,639	47,100	215,739
1986	115,992	26,404	26,247	10,173	20,630	7,296	0	0	167,869	47,873	215,742
1987	115,350	26,996	26,232	10,194	20,515	7,456	0	0	167,097	48,646	215,743
1988	114,709	27,588	26,217	10,215	20,400	7,616	0	0	166,326	49,419	215,745
1989	114,067	28,180	26,202	10,236	20,286	7,776	0	0	165,555	50,192	215,747
1990	113,426	28,772	26,187	10,257	20,171	7,936	0	0	164,784	50,965	215,749
1991	112,784	29,364	26,169	10,278	20,056	8,096	0	0	164,009	51,738	215,747
1992	112,143	29,956	26,154	10,299	19,941	8,256	0	0	163,238	52,511	215,749
1993	111,501	30,548	26,139	10,320	19,827	8,416	0	0	162,467	53,284	215,751
1994	110,860	31,140	26,124	10,341	19,712	8,576	0	0	161,696	54,057	215,753
1995	110,219	31,732	26,109	10,362	19,597	8,736	0	0	160,925	54,830	215,755

1/ Includes 5 million board feet in Douglas-fir and 4 million board feet in associated species from selected cutting.

Table 6.--Annual timber volumes by cutting method and timber type for roadbuilding at 450 miles per year

(In thousand board feet)

Year	Clearcutting		Salvage		Prelogging		Thinning		Total[1/]		
	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	Douglas-fir	Associated species	All
1966	132,211	10,027	54,879	10,080	0	0	5,203	5,772	197,293	29,879	227,172
1967	123,850	18,335	46,596	18,432	0	0	5,203	5,772	180,649	46,539	227,188
1968	115,345	26,786	38,172	26,928	0	0	5,203	5,772	163,720	63,486	227,206
1969	106,840	35,237	29,745	35,424	0	0	5,203	5,772	146,788	80,433	227,221
1970	109,919	35,810	24,429	36,000	0	0	4,932	5,330	144,280	81,140	225,420
1971	116,140	36,204	16,216	6,476	21,776	8,168	1,740	92	160,872	54,940	215,812
1972	121,755	30,223	16,646	6,487	21,713	8,256	1,740	92	166,854	49,058	215,912
1973	121,408	30,548	16,638	6,499	21,651	8,336	1,740	92	166,437	49,475	215,912
1974	121,079	30,844	16,630	6,509	21,592	8,424	1,740	92	166,041	49,869	215,910
1975	120,732	31,170	16,622	6,521	21,530	8,504	1,740	92	165,624	50,287	215,911
1976	111,065	31,466	25,587	10,140	19,801	8,592	0	0	161,453	54,198	215,651
1977	110,717	31,791	25,579	10,152	19,740	8,672	0	0	161,036	54,615	215,651
1978	110,394	32,087	25,571	10,161	19,677	8,760	0	0	160,642	55,008	215,650
1979	110,041	32,413	25,562	10,174	19,615	8,848	0	0	160,218	55,435	215,653
1980	109,693	32,739	25,554	10,185	19,552	8,928	0	0	159,799	55,852	215,651
1981	109,368	33,035	25,546	10,196	19,490	9,016	0	0	159,404	56,247	215,651
1982	109,022	33,360	25,538	10,207	19,428	9,096	0	0	158,988	56,663	215,651
1983	108,699	33,656	25,530	10,218	19,365	9,184	0	0	158,594	57,058	215,652
1984	108,350	33,982	25,522	10,230	19,304	9,264	0	0	158,176	57,476	215,652
1985	108,027	34,278	25,514	10,240	19,241	9,352	0	0	157,782	57,870	215,652
1986	107,680	34,604	25,505	10,251	19,179	9,432	0	0	157,364	58,287	215,651
1987	107,355	34,900	25,497	10,262	19,117	9,520	0	0	156,969	58,682	215,651
1988	107,008	35,225	25,489	10,273	19,055	9,600	0	0	156,552	59,098	215,650
1989	106,686	35,521	25,481	10,284	18,992	9,688	0	0	156,159	59,493	215,652
1990	106,332	35,847	25,473	10,296	18,930	9,776	0	0	155,735	59,919	215,654
1991	105,984	36,172	25,465	10,307	18,868	9,856	0	0	155,317	60,335	215,652
1992	105,661	36,468	25,456	10,318	18,806	9,944	0	0	154,923	60,730	215,653
1993	105,313	36,794	25,448	10,329	18,743	10,024	0	0	154,504	61,147	215,651
1994	104,989	37,090	25,440	10,340	18,682	10,112	0	0	154,111	61,542	215,653
1995	104,641	37,416	25,432	10,351	18,619	10,192	0	0	153,692	61,959	215,651

1/ Includes 5 million board feet in Douglas-fir and 4 million board feet in associated species from selected cutting.

Table 7.--Annual dollar benefits from timber harvest for five alternative roadbuilding plans

(In thousand dollars)

Year	Rate of roadbuilding (miles per year)				
	75	100	150	250	450
1966	7,433	7,478	7,567	7,753	7,952
1967	7,411	7,453	7,531	7,655	7,638
1968	7,389	7,429	7,495	7,558	7,318
1969	7,370	7,401	7,457	7,455	6,999
1970	7,347	7,376	7,421	7,357	6,908
1971	7,325	7,350	7,385	7,260	8,310
1972	7,303	7,326	7,349	7,157	8,358
1973	7,281	7,301	7,313	7,060	8,351
1974	7,262	7,273	7,275	6,903	8,344
1975	7,240	7,248	7,236	8,598	8,337
1976	7,165	7,170	7,150	8,532	8,291
1977	7,143	7,145	7,114	8.519	8,284
1978	7,121	7,120	7,078	8,506	8,277
1979	7,099	7,092	7,039	8,493	8,270
1980	7,079	7,067	6,853	8,479	8,263
1981	7,057	7,042	8,610	8,467	8,256
1982	7,035	7,017	8,593	8,453	8,249
1983	7,013	6,992	8,576	8,440	8,242
1984	6,991	6,964	8,559	8,427	8,235
1985	6,972	6,940	8,542	8,414	8,228
1986	6,950	6,915	8,525	8,401	8,221
1987	6,928	6,890	8,508	8,388	8,215
1988	6,905	6,159	8,490	8,374	8,208
1989	6,883	8,475	8,473	8,361	8,201
1990	6,864	8,457	8,456	8,348	8,194
1991	6,839	8,440	8,439	8,335	8,187
1992	6,820	8,423	8,422	8,322	8,180
1993	6,798	8,406	8,405	8.308	8.173
1994	6,776	8,389	8,388	8,295	8,166
1995	6,754	8,372	8,371	8,282	8,159

Table 8.--Annual road construction and maintenance cost for five alternative roadbuilding plans

(In thousand dollars)

Year	Rate of roadbuilding (miles per year)				
	75	100	150	250	450
1966	2,250	3,002	4,505	7,513	13,527
1967	2,250	3,004	4,511	7,526	13,555
1968	2,250	3,005	4,516	7,538	13,582
1969	2,250	3,007	4,522	7,551	13,610
1970	2,250	3,009	4,527	7,564	12,584
1971	2,250	3,011	4,533	7,577	129
1972	2,250	3,013	4,538	7,589	123
1973	2,250	3,015	4,544	7,602	118
1974	2,250	3,016	4,549	6,562	112
1975	2,250	3,018	4,555	107	107
1976	2,250	3,020	4,560	101	101
1977	2,250	3,022	4,566	96	96
1978	2,250	3,024	4,571	91	91
1979	2,250	3,026	4,577	85	85
1980	2,250	3,027	3,530	80	80
1981	2,250	3,029	74	74	74
1982	2,250	3,031	69	69	69
1983	2,250	3,033	63	63	63
1984	2,250	3,035	58	58	58
1985	2,250	3,037	52	52	52
1986	2,250	3,038	47	47	47
1987	2,250	3,040	41	41	41
1988	2,250	486	36	36	36
1989	2,250	30	30	30	30
1990	2,250	25	25	25	25
1991	2,250	19	19	19	19
1992	2,250	14	14	14	14
1993	2,250	8	8	8	8
1994	2,250	3	3	3	3
1995	1,200	0	0	0	0

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Payne, Brian R.
1972. Accelerated roadbuilding on the North Umpqua--an economic analysis. USDA Forest Serv. Res. Pap. PNW-137, 32 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Accelerated construction of roads for access to old-growth timber on a unit of the Umpqua National Forest in Oregon was found economically undesirable, using the then-current (1966) roadbuilding rate.

Keywords: Forest roads, forestry economics, logging.

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